Digital Circuits
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Lecture – 02
Introduction (Contd.)

So, this is a digital signal representation so, this I gives us the flexibility, by which we can think about digital processing of this signals from the environment. So, this analog signals that we are getting so, if we want to process them digitally. So, we have to think about their representation, because anything that you want to do first of all what is required is to ha store the information that we have got from the outside world and for storing the information. So, you have to go for this digital form only.

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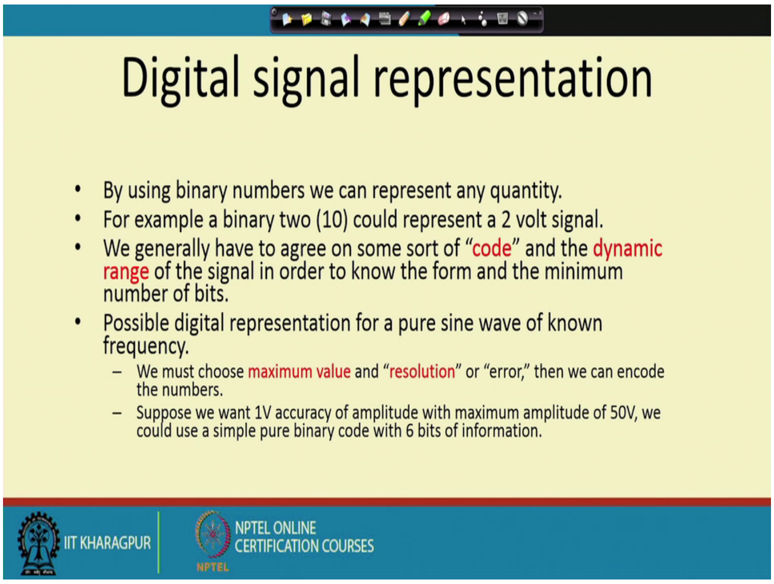

So, by using this binary numbers we can represent any quantity. So, we will see in our course that this by the different number systems are possible, and in a computer system, the number system that is used is the binary number system so, where this individual digits are only once and 0s.

So, what we can do this we can represent 2 different state of some signal by means of these 2 different notations 0 and 1. So, may be if it is some voltage value we can say that this 0 is 0 volt, and 1 is 1 volt like that. Or if it is a say 0 is 0 volt, 1 is 5 volt, or it may be 0 is minus 12 volt and 1 is plus 12 volt, or the other ways 0 is minus 12 volt, sorry, 0 is plus 12 volt and 1 is minus 12 volt. So, like that we can have different type of conventions that we follow.

But ultimately the information that we store so, that is in some digital format. So, for example, you can have this binary 2. So, 2 is represented by 2 bits 1 0 that could represent a 2 volt signal. So, if we say that one binary one corresponds to a one volt signal. So, you can say that the binary value 2, it corresponds to a 2 volt signal.

So, we generally have to agree on some sort of code. So, what that is what I was talk talking about some time back. So, you can say that say minus 12 volt is 0 and plus 12 volt is 1, or somebody may say that the plus 12 volt is 0, and minus 12 volt is 1. So, of them are possible so, if you look into different systems, we will see that the all these types or different types of representations are possible.

So, we must agree on some sort of coding that we have and the dynamic range of the signal that we want to represent. So, se whenever we are talking about some representation of a number. So, we are dedicating certain number of bits in it, certain number of digits for that purpose so, using that many digit. So, you cannot represent any arbitrarily high number. So, if I say that I have a number of system, I have a space to write only say 3 digits. So, I cannot use it for representing the number 2, 5, 5, 6 in that system; because that requires 4 digits 4 digits space, but we have only a single digits 3 digits space so, I cannot have 4 digits there.

So, this way we can think about this range. So, this range dynamically what the what the values that signal can peak up so, we must know that and accordingly we have to decide the minimum number of bits that will be using for storing that information. Possible digital representation of a pure sine wave of known frequency, for that purpose we must choose the maximum value. So, what is the maximum peak value that we have, and resolution or error that is at what level at what difference of values you are going to take, ok.

So, we will take suppose you want to one volt accuracy ok. So, suppose that is the and the maximum amplitude is minus is 50 volt. Maximum amplitude is 50 volt that is the signal goes from say minus 25 volt to plus 25 volt in the 2 ranges.

So, if we say that the minus 25 volt, I will represent as 0, then 20 minus 24 volt, I will represent it as 1 minus 23 volt, I will represent it as 2. So, like that if we think about this type of levels, then ultimately for this minus 25 volt to plus 25 volt, this 50 volt range I will have 50 different levels of the signal, that we can gave so, if we think about one volt accuracy.

So, as a result so, this 50 different values have to be represent it, and in a binary number system will see that it will require 6 bits to store that information. So, if you are given less number of bits. So, you will not be a able to represent this 50 different levels. So, or a so, you have to suffer on the accuracy side ok. So, suppose instead of say 50 different level so, I want to store I want to have I am given only say 5 bits. So, with 5 bits so, I can have 32 different levels possible only. So, accordingly my accuracy will be less for the signal.

So, this way this digital signal representation itself it introduces some amount of error. So, if we are go, if we are looking for these exact values if we are looking for exact value when we have to go for the analog signal definitely, but as soon as we go for this digitization process some amount of error is introduced into the system so, that is there.

But we will see that there are different types of errors that can crop up into this analog systems, and that makes the digital systems much better from that point, but as for as the initial quantization is concerned. So, digital signals they have got some amount of error associated with it.

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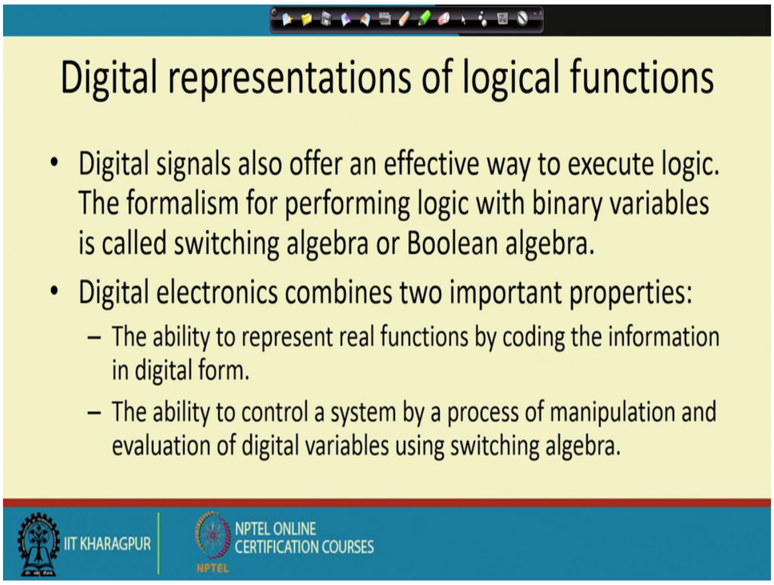

So, how can we represent digital logical functions in digital representation. So, digitals signals they offer an effective way to execute logic. The formalism of performing logic with binary variable is called switching algebra or Boolean algebra.

So, when we talk about algebra so, the term algebra means that there will be some values that you can that that individual variables can peak up so, that is there. And I can do some operations on that, on those values. So, there are certain there will be some axioms or fixed accepted norms for that particular system, and then on that we can build up the total set of computations.

So, in case of digital signals, so, we will seed that, this Boolean algebra or switching algebra. So, that makes the basic foundation stone for developing the system. And may be knowing that this Boolean algebra. So, this was the discovered long below these digital circuits came into existence, and that that time it was pure mathematical interest, but once this digital systems got introduced, then this again this Boolean algebra got it is importance back.

So, this digital electronics when we are talking about it combines 2 important properties. One is the ability to represent functions by coding the information in digital form. So, that is one one property. And the other property is that it can control a system by a process of manipulation and evaluation of digital variables is in switching algebra. So, you can do some computation you can find out, you can have a set of conditions for which certain signal said to be turned on.

For example, if you if you in a plant control so, there are may be different conveyor belts moving. Then items are being put on to conveyer built, then they apart from the there may be some fires safety system so, if you have smooch detector is sending signals. So, like that there may be a large number of signals the inputs that you can get from the plant, and accordingly you may have to do a set of other operations.

So, in this process they can be represented by means of some logical equation or logical functions, and those logical functions or those controls functions they can be implemented by means of this they can be represented by means also switching algebra. And once you have represented them using switching algebra so, you can implement them using digital circuits.

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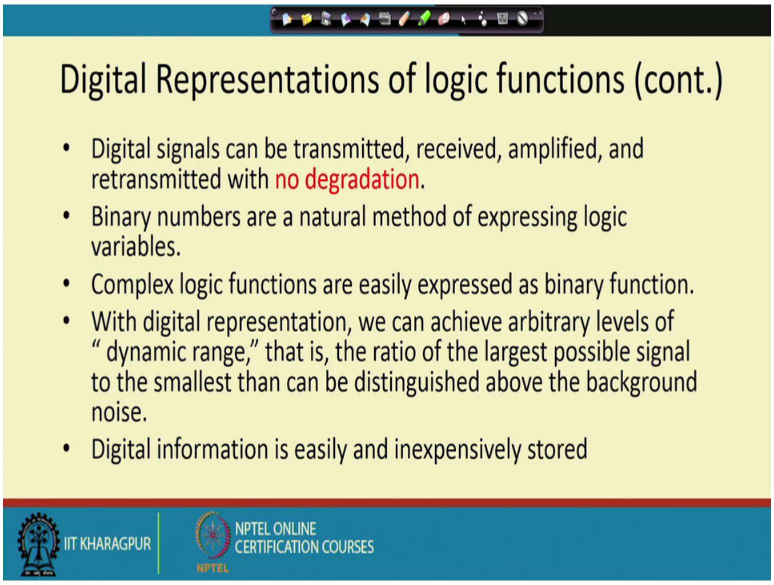

So, digital signals so, this is the next we going to why digital signals are preferable. So, digital signals can be transmitted received amplified and retransmitted with no degradation. So, why do I say so, because if you are transmitting some digital value. So, you know that the ultimately, what is transmitted is a bit 1 or 0. So, when you are transmitting a bit as 1 or 0 at the receiving station.

So, if I say that 1 in my system, 1 is represented by plus 12 volt and 0 is represented by minus 12 volt. So, at the receiving station, if you get some intermediary value; say, minus 5 volt. So, you can say that the minus 5 volt is close to minus 12. So, that is that can be taken as 0. So, that way we can we can say that even if I have got some values degraded, but digitally the value is the not degraded digitally the, we can still take it back to 0.

So, this binary numbers so, there they are natural method for expressing this logic variable. And complex logic functions can be easily expressed as binary functions. So, we will as I was telling that, in a plant there may be different inputs coming from different regions. And then we can have the overall plant function specify the in terms of this control operations that it is doing, and that may be a set of logic functions, and they are represented as binary function and from there we can get the function implemented in digital circuits. So, we can achieve arbitrary levels or dynamic range that is the ratio of the largest possible signal to the smallest one can be distinct that can be distinguished above the background noise.

So, what happens is that so, whenever you are transmitting a signal there is always some amount of noise that we will get added into the systems. So, if you are transmitting some analog signal so, you can say that the analog signal say suppose I am transmitting a value of say 12 volt. And due to the this noise so, this value becomes degraded to say 7 volts; say, there is a noise introduced of minus 5 volt and at a some instant, and it becomes 7 volt.

So, at the receiving end I do not know whether value was a value is really 7 volt or it is 6 volt or it is 12 volt or something is intermediaries so, that way we cannot find out the thing. But if we say that in case of in case of digital one so, if I know that plus they one will be transmitted as 12 volt, and 0 will be transmitted at minus 12 volt. So, we can safely say anything above 0 is possibly 1 and anything below 0 0 volt so, it is possibly a bit 0. So, this is the amount of that the noise margin the noise immunity that we have in the digital system. So, it is going to be much more compare to the analog system.

So, digital and the last point is the digital information it can be easily and inexpensively stored. So, we can store this values in the; so, with the advancement of this DRAM technique tech technology and all, SRAM technology and all. So, we store large amount of information digitally in the system, and the quality is also much better than the analog storage.

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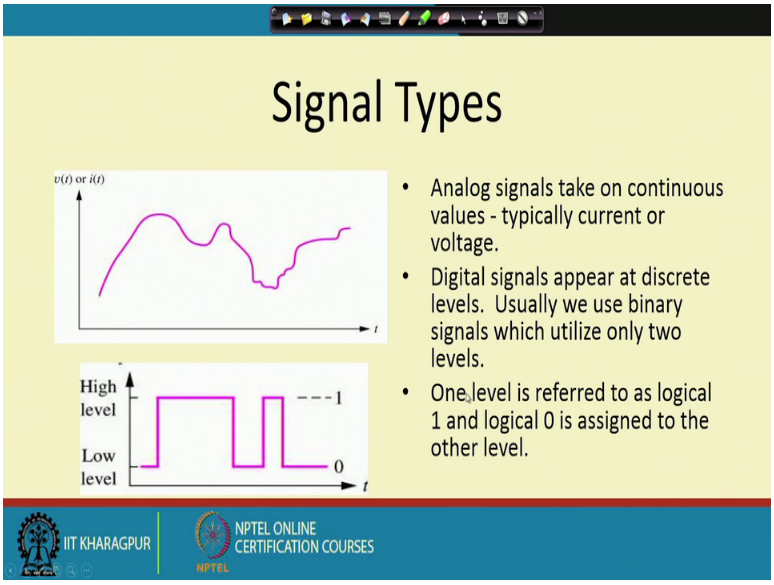

So, so, what you mean by this analog signal or digital signal? So, the first diagram that you see here so, this is an analog signal. So, for the time so, this the it may be a voltage signal or a current signal. So, it is varying like this so, this is the analog signal. So, analog signals take on continuous value so, there is you cannot say that at difference there is nothing like at different. So, this is normally is specified into terms of some function over time or maybe a say differential equation and all, but ultimately this is a continuous function of time. So, typically a current or voltage may be representing an analog signal.

A digital signal so, they appear at some discrete levels. So, usually we use the binary signals that it only 2 levels like here you see that we can have a low level and a high level. So, this may be for this for this much of time the signal was low. Then for the this range of time the value is 1, then again for this range the value is 0 again it is 1. So, one level is refer to as logic 1, and the other level is refer to as logic 0.

So, of course, the it is not mandatory that this high level should be one and low level should be 0. Somebody may say that my high level is 0 and the low level is 1 that is very much possible. But what is what is required is that there are 2 distinct level. So, one of them is called logic 0, another one is called logic 1. So, we have got different this is a digital signals. So, they are going to be discrete in terms of level so, it is not a continuous function like that.

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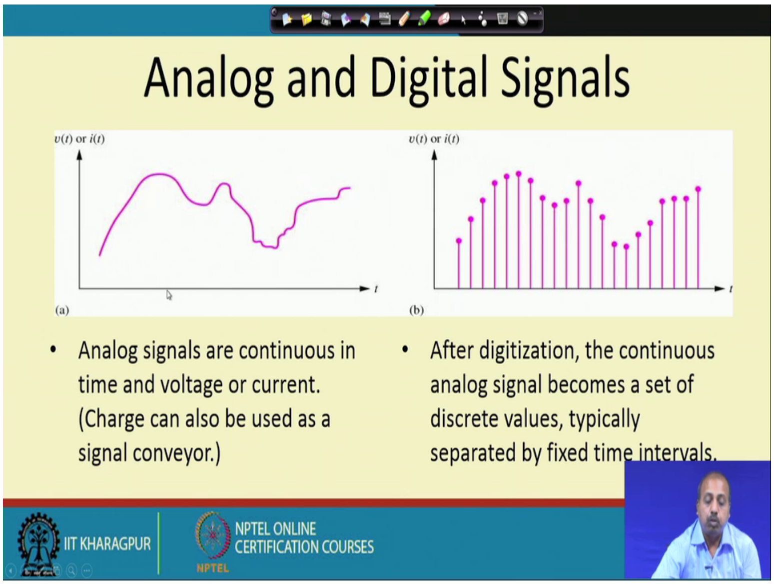

So, with that so, if we have got an analog signal. So now, I cannot have information's told for every time instance in my digital system. Like so, analog signals are continuous in time and voltage or current. So, like say so, we can so, or charge so, that way we can have this analog signals represented over time, but when you do a digitization.

So, at every point we basically do a sampling. So, at some regular intervals of time so, we sample these digital signal, and then what we get is over the time intervals after separated by time intervals we get some signal samples. So, the after digitization this continuous analog signal it becomes a set of discreet values only. So, they are typically separated by this fixed time interval. So, which is known as the, which is this is a typically this is known as the sampling interval after this sampling intervals, the value is a sampled again and this values are stored.

So, ultimately for digital signal so, what we will need to do is that we need to store the values of the signals at this discreet points only. So, if you are willing to do a good approximation of the analog signal the, we have to do a sampling at a much higher rate, and if you are not so, then you can do where sampling at a lower rate also. And from the communication theory you can find out like what is the minimum rate at which we have to do the sampling and all for periodic signals etcetera for the construction purpose.

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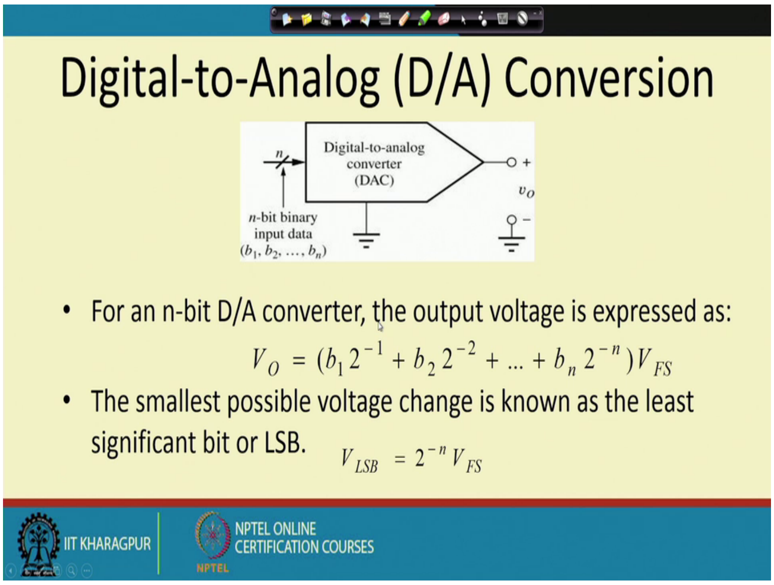

The important modules that we have in this process, one is the digital to analog converter so, or DSC. So, digital to analog converter will come when this after doing this digital processing. So, we are trying to give some signal to the environment. So, the and the environment is analog so, we have to give some analog signal.

So, these in bit digital value, that is coming as input to these digital to analog converter module so, it produces a voltage level. So, you can say that if this in general. So, it is ah, if we FS is the voltage the full scale voltage we say VFS 0 to VFS are the values. Then based on these values that we have got so, if all these b 1 b 2 bn. So, if all these bits are 0s, then what you get is 0 at the output. So, if you are giving a all 0 here you are getting a 0 output here.

On the other hand if you are giving all these bits as 1, so, you will getting a very close, you will be getting the expression V o will be very close to VFS, ok. It is be just slightly less than this VFS so, which is basically because of so, that that way you will get a value which is very close to VFS so, you can say that. This is the voltage level that you are getting so, that you are getting the full scale range.

So, that way this digital to analog converters; so, they are useful for converting the digital value that we have got, after processing into some analog signal for said to be send to the environment. So, what is the smallest possible voltage change? So, since this is a this is a. So, change the value can you can vary this bits, and since this quantity b n into 2 power minus n.

So, these has got the minimum contribution so, if you are going to change from the smallest possible change that you can do is by changing this flipping this particular bit bn. And that way this minimum change that is possible is the 2 power minus n into VFS. So, this we called the least significant bit or LSB.

So, that is the 2 this nth bit is the significant bit or the LSB. So, by changing this LSB, we can get this much of change so, this is the quantum this is the quantization level. So, you cannot represent voltage change which is finer than these 2 power minus n into VFS. So, you cannot get better than that. So, so, that way this will have the error part.

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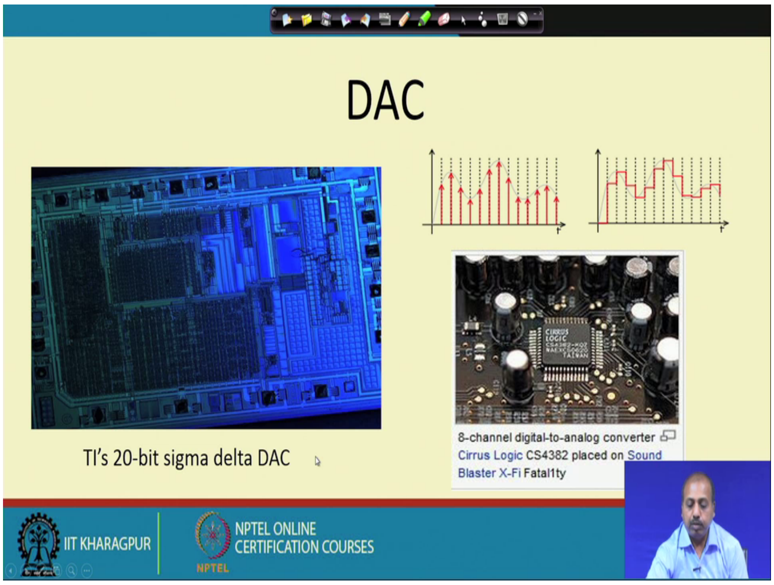

Similarly we have so, this is another, this is the commercial d some commercial DAC. So, this is Tis 20 bit sigma delta DAC, then this is an 8 channel d DAC from cirrus. So, like that so, essentially what is happening is; so, this light colored signal. So, this is the analog signal that we have so, and these are the samples.

So now, if you are if you are doing a digitization so, this is basically getting approximated like this. And then so, so, this is digital values that we have. So, that is converted into levels like this. So, this signal that we are getting is a close approximation of what we actually want. So, that way we say that these digital to analog converters are doing the conversion.

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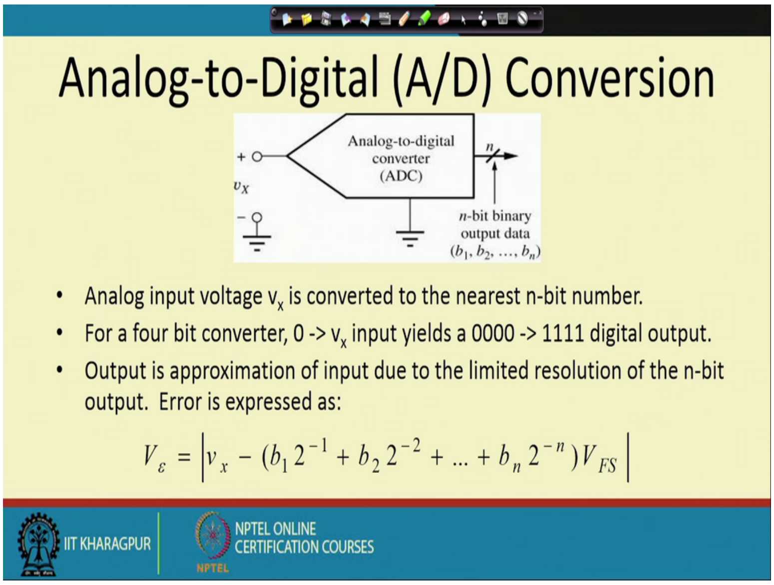

The other component the opposite if this is the analog to digital conversion. So, where on this analog side some value is coming, and then we want to convert it into some digital value. So, like a say one conveyor belt is moving, and you are just trying to see what is the speed at which it is moving.

So, the speed is coming as an analog quantity a some analog or some transducer will be there, and it will be coming as a analog signal. And that analog signal we want to convert digital values so, that we can do some processing we can either increase or decrease it like that. So, that way we can have the analog to digital converter on that side. So, this analog input voltage vx so, it will be converted to nearest n bit number.

So, again the same thing that for a 4 bit converter so, 0 represent the vx so, the so, if you 0 to vx. So, that will input yield 0 0 0 0 to 1 1 1 1 digital output. So, when you give a 0 as input so, you will get 0 0 0 0. When you give the maximum value vx as input so, you get 1 1 1 1 as the digital output. So, that is the design principle of this analog to digital converter.

So, we will see later in our course how to design this ADC’s and DAC’s in different ways. But however, ultimately this is the thing that we want so, if we give a 0 voltage.

So, it should 0 0 0 0 if we give vx the maximum possible voltage, then it should give all one.

So, output is again approximated approximation of the input data, to the due to the limited resolution of this n bit output. So, error that we have so, this is the actually the vx that we want to represent, but what we actually get is this one. So, these bits that are coming. So, if all these bits are one then you will be getting a value which is very close to VFS, but this value is VFS.

So, this VFS minus that approximation that gives the amount of error that you have in the process. So, this way we can have the analog to digital conversion so, this DAC and ADC they are 2 very important modules that we have in a digital system when it is interfaced with the analog domain. So, we will see that due code sometime.

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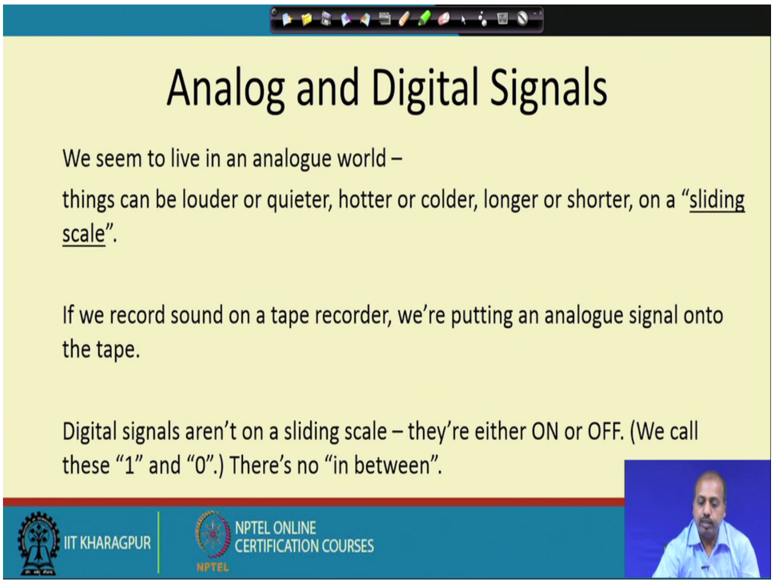

So, if you look into this analog and digital signal so, it seems that we are we live in analog worlds. So, things like we make the statements like louder quieter hotter colder longer shorter. So, this is the sliding scale so, may be if I say that make it louder. So, you just increase you will not turn the knobby bit, and may be the may be unsatisfied that is ok or, I say the no, no reduce it a bit. So, make it quieter so, like that so, that is an analog signal.

When your recording some sound on a tape recorder. So, we are putting the analog signal on to the tape, the and digital signals are not on a on a sliding scales so, they are either on or off like switches. So, the either the switch is on or the switch is off there is nothing like a light is turned half on. Of course, if there may be intensity control of the light so, that maybe if they are may be some on some analog some sliding scale may be there.

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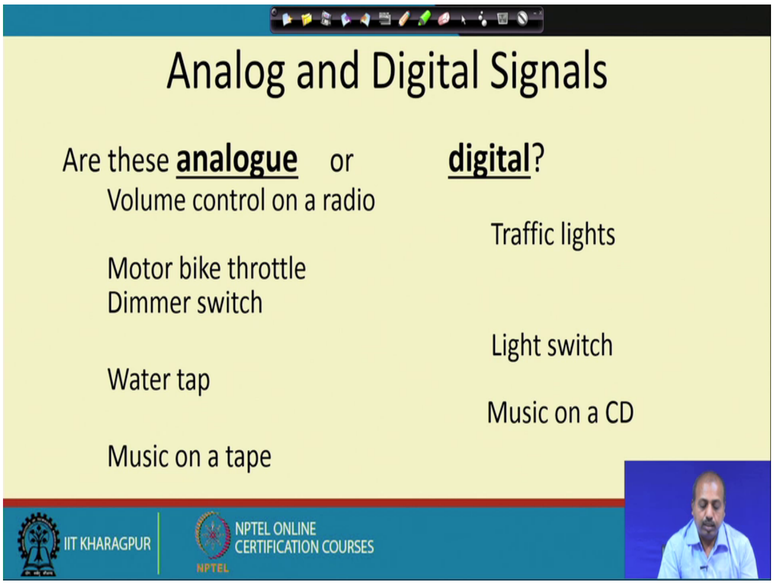

So, if we just look into some of the signal and try to see whether it is analog digital. So, this volume control on a radios so, this is an analog signal traffic lights. So, they are either on or off so, they are digital. So, this green red and yellow, either they are on or they are off. Motor bike throttle, the amount of fuel injected into the system. So, that is going to be an analog signal, because with the place of the as we turn this accelerator. So, it puts in more and more fuel.

The dimmer switch; so, if we you can control the amount of illumination. So, that is also an analog signal whereas, a light switch with just turn on or off the light. So, that is going to be a digital signal. Water tap so, this is again an analog signal ok, we can turn the tap as much as you want and accordingly the amount of water passing will vary. Music on a CD is a digital signal. So, CD is the compact disc, they store information on a digital format. And music on a tape so, that is going to be an analog signal. Because they are uses analog principle to store the information.

So, this way different different signals so, you can think about them in digital or a analog, but most of the signals or the most common signals that we have so, they are all analog in natures. So, we have to pass them to an analog to digital convertor to get the corresponding digital versions. And if we are trying to produce an analog signal through some digital processing, we have to produce a, we have to have digital to analog convertor for converting the digital value to analog.

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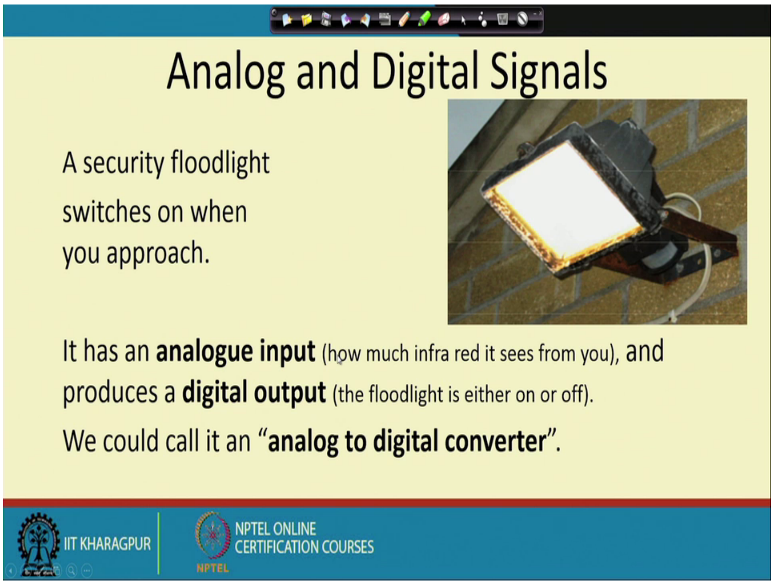

So, this is another typical example of analog and digital signals so, a security floodlight. So, it switches on when you approach so, it may be it has got an analog input. So, it senses the infrared the amount of infrared that it sees from you. And produces a digital output so; floodlight is either turned on or off. So, when it is doing that sensing of this infrared component.

So, that is an analog signal, it is an analog input, but when it is producing this floodlight, once it is turned on it is either turned on or turned off so, that is going to be a digital signal. So, we can call it an analog to digital converter in that sense, ok. So, so that is one way of the ADC that you can see.

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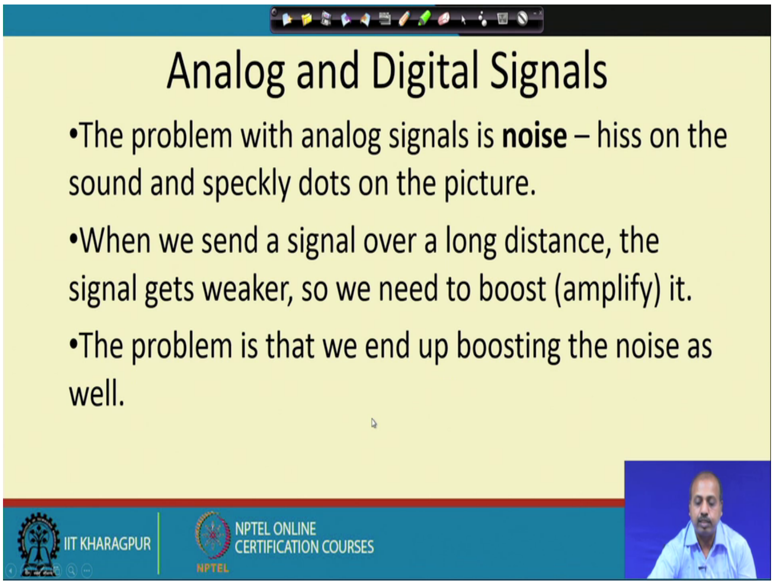

What is the problem with analog signal is the noise. So, the lot of noise gets introduced; like, if you are the further sound, they are may be a that get introduced. Or if it is an image or picture these speckly dots may get introduced into the picture due to these errors, the or the, that got introduced you from the noise.

So, when we are sending a signal over a long distance the signal will get weaker because of losses, and we need to boost the signal; otherwise, you have transmitted as I was telling so, you transmitted as I was telling. So, you are transmitted 12 volt and over the length. So, it got reduced maybe so much that you get a very low voltage there. So, that way a you need to amplify in between, ok.

So, normally what we do is that we put some periodic amplifiers on the path, and then the amplifier amplifies the signals a boosts up the signal so that at receiving end you get reasonably correct signal.

So, the problem is that we end of boosting the noise as well the process. So, in the if we have got a boosting station so, a previous to that in the previous segment some noise got introduced. So, that noise will also get boost up in the process. So, this noise also gets amplified or noise also get booster. So, that is the problem with the analog signal.

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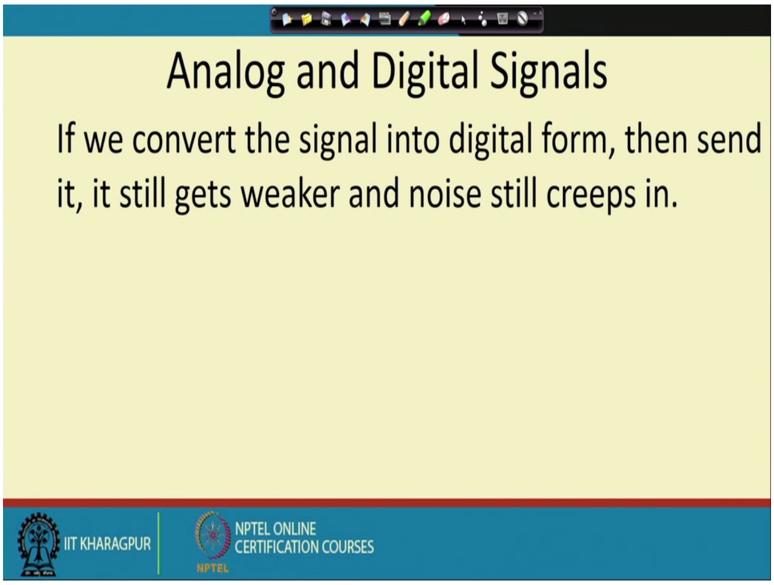

So, if we on the on the other hand, the digital signals if we convert the signal to the digital form and then send it, still gets weaker, and noise will still noise still creeps in. Because that is the ultimately what we transmit is some analog voltage values. So, that will be that will make the signal weaker and the noise will come. So, there is no doubt about it, but it is like this.

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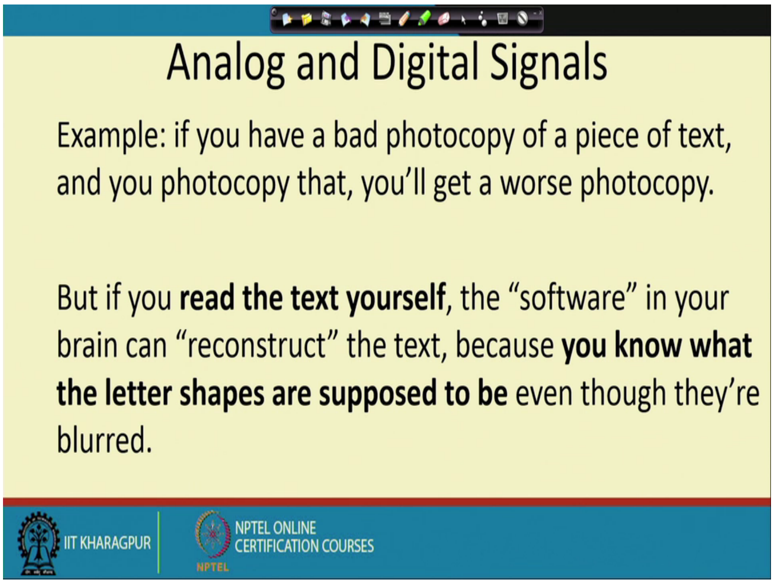

If you read the text yourself, the software in your brain can reconstruct the text, because you know that ah. So, because you can the, that the later shapes are suppose to be even though they are blurred. So, like if you do a photocopy of a page with the page which is not very clear ok. So, if you do a photocopy so, after copy we will get a even worse page.

But if you do it like this if you read the text from the page. So, possibly you will be able to figure out those blurrings of the different laters that we have on the page, and we can just correct it. So, this is just what this digital thing does. So, will maybe the voltage value has reduced a bit, but it is not that much degraded and still possibly we can figure out that this was a on and this was a 0. We can reconstruct the signal and then again in transmit. So, that away the amount of noise that we got introduce so, that may get reduced further.

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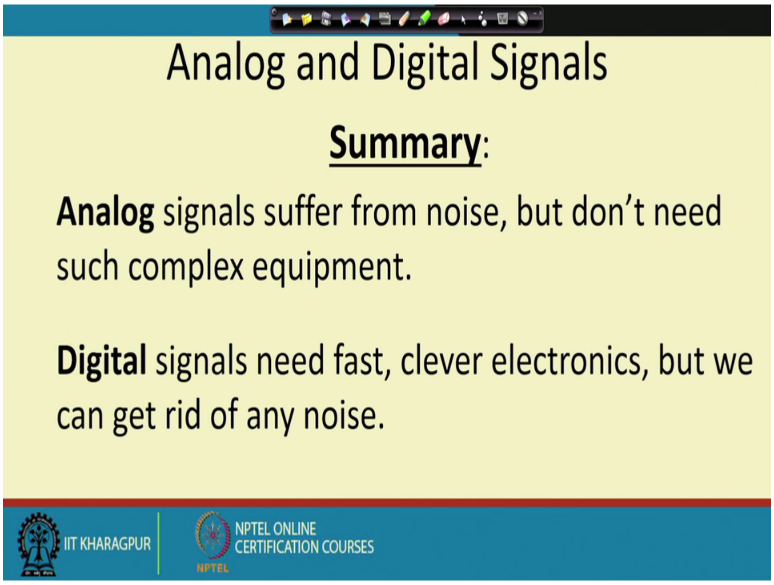

So, analog signal the suffer from noise, but do not need such complex equipment. On the other hand, the digital signals need fast clever electronics, but we can get rid of any such noise. So, this is the so, that tells the summarize is the analog and digital signals.

So, one of the very basic components when we are doing this the digital switching and digital circuits so, is the is a transistor and the most recent transistor that is being used in the digital industry today.

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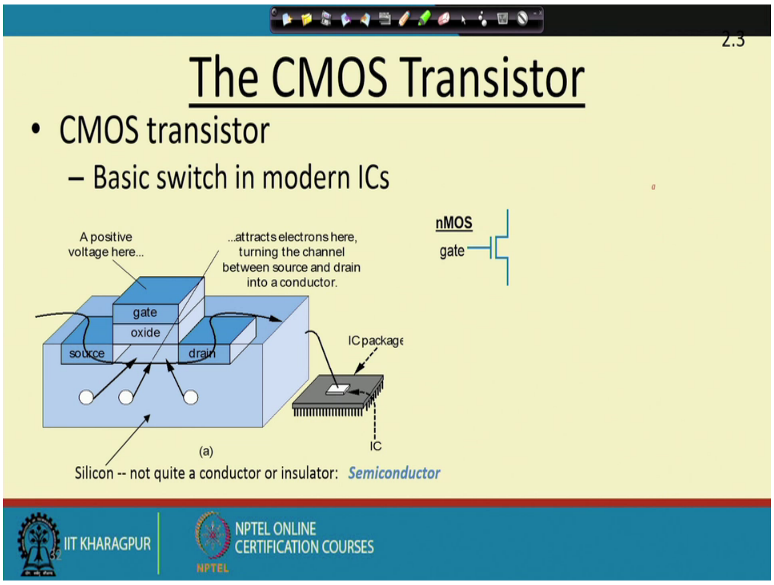

So, they are CMOS transistors so, in CMOS transistor so, we will discuss in detail later just to tell you how it works.

This is a semiconductor block, so, so that so, normally. So, this is on that semiconductor block we have got 2 dedicated region one is called a source another is called drain. So, they have got some type of diffuse, they are some amount of some type of diffusion basically. So, if this semiconductor block that we have. So, if this is of say p type semiconductor then on this 2 regions so, we put some n type diffusions. So, one region is called source, other region is called drain.

So, the region in between so, it is covered by some silicon dioxide layer, and on top of that we put a another layer of policy we can get. Now normally what happens is the if we apply a voltage on to this gate positive voltage on to this gate so, it will it will attract the electrons from this from the substrate, we call it a substrate. So, the it will call the it will attract this electrons into this into this channel between the source and drain, and now if there is a potential difference between source and drain.

So, if we apply a battery between the source and drain, then these electrons will move through this channel they will go from source to drain or drain to source depending on the polarity of the signals.

So, you get a current flow through the through the device if we apply a positive voltage here. So, it will attract electrons turning the channel between source and drain into a conductor. So, this region will behave as a conductor. So, that is why it is called a semiconductor so, will be. So, if turn for turning of the connect conduction so, you just make the get a 0. And so, this is track this channel will go. So, there is no conduction, and if you want this channel to be on so, you just apply a voltage here. So, this channel will become on.

So, pictorial it is represented like this. So, we have got source and drain at the 2 ends, and there is a gate control. So, if you apply logic high here, high voltage here, then the channel will come to existence as a result you can see that the as if this transistor is now open. So, transistor is now on so, you can get a conduction from this side of the transistor to this side of the transistor through the channel.

The other hand if you put a logic 0 here a low voltage here or you withdraw the voltage that you are apply. So, this channel will low will not exist as a result, this transistor will behave as if the transistor is open. So, this is this is this will behave like a open switch.

So, in one case it is working as a closed switch, when this when this gate is high so, this will act as a closed switch. So, you will get connection from here to here, and another case you will getting an getting an open situation where there is no connection from get to drain to source. So, this way this transistor will behave in the form of a switch.

So, we will come back to these transistors again later, but what I essentially means is that these are the, these small transistor. So, they are the tool by which we represent this switches in the digital circuits. So, they will be used again and again for when in the circuit design.